SECTION 3

SUMMARY OF THE PLENARY SESSION

3.1 Plenary Session

3.1.1 USEPA's Mercury Research Strategy — *Douglas W. Grosse, USEPA, National Risk Management Research Laboratory (NRMRL)*

- USEPA released the *Mercury Research Strategy* in December 2000 to guide ORD's Mercury Research Program. The focus of the research strategy is on domestic impacts of mercury.

- The *Mercury Research Strategy*
  - outlines and summarizes the health and ecological risks posed by mercury.
  - indicates that mercury needs to be considered on local, regional, and global scales.
  - identifies key scientific questions of greatest importance to the Agency.
  - describes a research program to be implemented to answer those questions.

- The goal of the *Mercury Research Strategy* is to "provide information and data that reduce scientific uncertainties that limit USEPA's ability to assess and manage mercury and methylmercury risks."

- ORD's Mercury Research Program is designed to provide methods, models, and data that address the following research areas: 1) transport, transformation, and fate; 2) risk management for combustion sources; 3) risk management for noncombustion sources; 4) ecological effects and exposure; 5) human health effects and exposure; and 6) risk communication.

- ORD research priorities to address the transport, transformation, and fate of mercury include
  - improved understanding of transport, transformation, and fate of mercury in the atmosphere.
  - enhanced monitoring of atmospheric mercury deposition for model application by developing better monitoring tools.
  - improved understanding of transport, transformation, and fate of mercury in aquatic and terrestrial environments.
  - enhanced monitoring of mercury and methylmercury in aquatic and terrestrial media for improved risk management.

- ORD risk management research priorities for noncombustion sources include
  - characterization of the mercury life cycle in human activities.
  - improved understanding of mercury releases from sources and sinks.

- development of approaches for minimizing mercury releases with pollution prevention, collection programs, and materials substitution.

- ORD research efforts addressing mercury effects and assessment will gradually increase in emphasis over the next 5 years. Research priorities in ecological effects and exposure include
  - improved understanding of methylmercury toxicity effects on avian and mammalian wildlife.
  - refined ecological assessments for avian and mammalian wildlife risks.
  - improved understanding of ecological impacts of methylmercury on avian and mammalian wildlife.
  - identification of interactions among methylmercury and other chemical and nonchemical stressors on all ecological receptors.

- When preparing the *Mercury Research Strategy*, ORD noted that the success of the Agency's risk assessment and risk management efforts relies on 1) improving mercury emissions inventories and collecting source emissions data; 2) monitoring mercury in various media; and 3) understanding the international implications of mercury (e.g., as it relates to the global pool).

3.1.2 USGS/USEPA Mercury Roundtable: Enhancing Interagency Collaborations — *Sarah Gerould, USGS*

- The Mercury Roundtable provides scientific input for future mercury program directions and initiatives. The Roundtable was developed to enhance interactions, technical support, and collaborations between the USGS and USEPA in the area of mercury.

- Roundtables have been held on the following topics from June 2000 to May 2001: 1) sources–mining and coal combustion; 2) cycling–transport, transformation, and fate; 3) effects–human health and wildlife; and 4) monitoring. Roundtables are planned on the following topics between August 2001 and April 2002: 1) historic trends–via sediment and ice cores and museum specimens; 2) modeling–aquatic and atmospheric; 3) arctic–deposition, risk to northern peoples, the "Arctic Sunrise" effect; and natural emissions–volcanos, oceans, geothermal sources.

- The USGS is actively researching a variety of mercury sources including coal combustion, mining, atmospheric deposition [to support the Mercury Deposition Network **(**MDN)], fire, and sediment.

- The USGS has also been working on a materials flow analysis of mercury that tracks contributions from the different sources (e.g., stockpile releases, mine production, secondary production, and net imports) and consumption associated with different types of uses (e.g., dental, instruments, batteries, switches, lighting, laboratory, paint, chlor-alkali). Results indicate that both domestic industrial mercury production and use declined in response to

legislation in 1984 banning its use in batteries and paint.

- The USGS has performed a number of mercury cycling studies that include the following sites: Carson River; Bear-Yuba and Trinity River; Everglades; Coast Range of Southwest Alaska; Minnesota reservoirs; Animas River; Sacramento River; Sierra Nevada mountains; Michigan; Wisconsin; Northwest Ontario, Canada; and Mississippi River.

- The USGS is also performing a number of studies on the biotic effects of mercury. One study is currently examining the demethylation process in fish-eating birds. This study is investigating why higher concentrations of total mercury are associated with lower concentrations of methylmercury in fish-eating birds. This study has implications on the burden of mercury passed on to eggs. The USGS is also involved in a study that injects mercury into bird eggs in order to assess the comparative toxicity of mercury on developing bird embryos.

- USGS has been involved in a number of monitoring programs that included mercury, including the National Water Quality Assessment (NAWQA) Program, which looked at mercury concentrations in fish tissue, and the MDN. The USGS is also involved in a number of studies that are assessing historical mercury concentrations using core sediment samples. These studies have associated rises in mercury with major land clearance activities in the 19th century.

3.1.3 State of Florida/Mercury Science Program—*Tom Atkeson, Florida Department of Environmental Protection (DEP)*

- The Florida DEP initiated mercury monitoring in 1983. These efforts ultimately led to the realization in the late 1980s that Florida had a mercury contamination problem. Until then, mercury contamination problems had not been identified in the southern latitudes. Research efforts in Florida added a new geographic dimension to the recognition of the mercury problem.

- After the initial recognition of the mercury problem, Florida soon developed approaches to address the problem. These efforts led to the founding of the South Florida Mercury Science Program. This program has evolved into a successful collaboration between state, Federal, and private agencies to fund and carry out mercury research in Florida.

3.1.4 USEPA STAR Program — *Bill Stelz, USEPA, National Center For Environmental Research (NCER)*

- ORD is the research arm of the Agency. Extramural research in ORD is mainly done through the STAR Program.

- ORD provides the leadership in science and conducts most of USEPA's research and development; NCER is ORD's extramural research arm.

- In cooperation with other USEPA offices and using the ORD Strategic Plan, national environmental research needs, relevance to Agency mission, and research being done in ORD's intramural program, ORD selects topics for the STAR Program.

- The STAR Program was established in 1995 as part of the overall reorganization of ORD. Its mission is to "include this country's universities and nonprofit centers in USEPA's research program and to ensure the best possible quality of science in areas of highest risk and greatest importance to the Agency."

- The STAR Program awards approximately $100 million dollars annually and manages about 1,000 active research grants and fellowships.

- The STAR Program makes yearly research announcements, some of which are repeated year after year, while others have been changed to reflect changes in the USEPA planning process, to meet Agency needs, or to complement in-house research efforts.

- Mercury Speciation and Atmospheric Chemistry was included in the general research announcements made in 2001. The application period opened on April 20, 2001 and closed on August 15, 2001.

- STAR Program progress and results are communicated to the public online via NCER's web site (http://es.epa.gov/ncer/) and through research summaries, annual science progress review workshops, scientific conferences, and email announcements.

3.1.5 Electric Power Research Institute — *Leonard Levin, EPRI*

- Improvements in mercury methods and data assessment have enabled mercury researchers to perform field studies that can be compared over time and space. Efforts have advanced to the point that integrative studies may soon be feasible using contemporaneous data sets that relate mercury trends in different cycling systems to source and effects research.

- The development of a large set of good quality data is critical to developing integrative studies. This data needs to be of appropriate duration in order to establish trends in mercury concentrations with a reasonable degree of certainty.

- Drops in mercury deposition have been paired to drops in sulfate deposition in various lake studies. Because sulfur and sulfur-reducing bacteria play a significant role in the methylation of mercury in aquatic systems, future research is needed to separate changes in sulfate concentrations from changes in mercury concentrations.

- It is clear that the long-range transport of mercury outside the local and regional scale may be significant. In 2000 EPRI estimated that ~2,300 megagrams of mercury is being emitted per year from global anthropogenic sources. Approximately 40% of this total is emitted from the Asian mainland and nearby islands. Since half of the mercury emitted globally is believed to be ionic mercury, with the remainder emitted primarily as elemental mercury and a small part as particulate phase mercury, roughly half of the mercury emitted globally will deposit near the source area; the remainder will go into the global background.

- Benign tracers need be developed to assess where mercury deposits relative to the source and mercury's effect on the local, regional, and global environments. Ideally, these tracers will be introduced to the sources and traced through the entire complex cycling of mercury.

- Recent experiments have used stable isotopes of mercury to trace the flow of mercury from source to receptor and to observe how these isotopes move through the ecosystems over time, with the hope of eventually allowing researchers to differentiate anthropogenic mercury from background or natural sources of mercury.

- EPRI is involved in estimating how rapidly mercury from background sources (e.g., mine waste disposal from closed operations; re-emission of mercury from all sources; and native mercury from crustal deposits, volcanos, and hot springs) moves into the free atmosphere and the general circulation.

- EPRI is involved in wildfire field experiments in the northwestern United States. Initial data indicate that fairly small wildfires introduce a relatively large amount of mercury to the atmosphere.

- Research that addresses 1) how mercury moves between different compartments as it cycles through the systems and 2) which sources and reservoirs contribute to mercury's eventual deposition to receiving waters and sensitive receptors (via fish consumption) is critical to determining potential mercury management steps and whether those steps will be efficacious within a reasonable time period.

3.1.6 National Wildlife Federation (NWF) Great Lakes Natural Resource Center — *Mike Murray, NWF*

- NWF is a national conservation and education advocacy organization which was formed in 1936 as a federation of state conservation groups. The Great Lakes Natural Resource Center is one of 10 NWF field offices. This office focuses on toxics research issues, including mercury.

- NWF's Clean the Rain campaign is an educational campaign to raise awareness of air deposition issues and the health and ecological effects of mercury. NWF also runs a regional and national effort to promote the virtual elimination of mercury releases from anthropogenic sources consistent with goals in the Clean Water Act and Great Lakes Water Quality Agreement.

- NWF has worked on a number of Federal mercury air issues, including
  - regulatory determination for air toxics released from power plants.
  - land disposal restriction regulations (for mercury-bearing hazardous wastes) and other Federal actions involving mercury.
  - the Great Waters Program/Air-Water Interface Action Plan, which discusses water quality impacts from air pollutants, and the Air-Water Interface Action Plan, an implementation plan developed by USEPA to address the goals defined in the Great Waters Program.
  - the Mercury Action Plan, which addresses both voluntary and regulatory actions to reduce mercury releases and exposures.

- NWF has also provided input on the following Federal and state mercury water issues:
  - Total Maximum Daily Load (TMDL) regulation revisions within the Clean Water Act (CWA)
  - TMDL stakeholder work in Ohio and Minnesota
  - review of individual TMDLs
  - water quality (human health) criteria development for mercury
  - effluent guidelines for mercury and other persistent, bioaccumulative and toxic chemicals (PBTs)

- NWF has provided comment/input on a number of human health/fish consumption advisories, including revisions to the USEPA RfD and the Agency for Toxic Substances and Disease Registry (ATSDR) minimal risk level for mercury.

- NWF also provides sector-specific support to hospitals, dental offices, and other sectors on pollution prevention, mercury disposal, and reducing mercury use and releases.

- NWF is involved internationally with the Canada-US Binational Toxics Strategy, which was signed in 1997 to implement the recommendations in the Great Lakes Water Quality Agreement. NWF has also recently become involved with the Department of Defense Logistics Agency's mercury stockpile and trade issues. NWF also plans to play a role in the United Nations Environment Program's efforts to conduct a global mercury assessment in 2003.

3.2 Keynote Speakers

3.2.1 Atmospheric Deposition Overview — *Gerald Keeler, University of Michigan*

Over the past decade, researchers have realized that the atmosphere plays an important role in the biogeochemical cycling of mercury.

Mercury Cycle in the Biosphere

- Mercury is emitted into the atmosphere in various forms (e.g., elemental, particulate, and mercuric chloride). Elemental mercury is the dominant form of mercury in the atmosphere. Elemental mercury is fairly insoluble and has a lifetime of 6 months to more than 1 year. Particulate mercury is emitted from stacks and other sources associated with particulate-phase matter.

- Once emitted to the atmosphere, mercury can be directly deposited to sensitive ecosystems or remain suspended in the atmosphere, where it is subject to a very complex chemistry. The current understanding of the biogeochemical cycles of mercury is oversimplified and does not fully address the heterogenous atmospheric chemistry in clouds.

- Atmospheric emissions data indicate that fossil fuel combustion is the leading source of mercury emission to the atmosphere. Although mercury emissions from fossil fuel combustion have dropped dramatically in North America, fossil fuel combustion remains the leading source of mercury to the atmosphere worldwide. Waste combustion and other sources also have a significant impact. According to results from the South Florida Atmospheric Mercury Monitoring Study (SoFAMMS), emissions from municipal and medical waste incinerators were largely mercuric chloride.

- Despite recent efforts to control mercury emissions, scientists continue to see elevated levels of mercury in runoff from urban areas and elevated background levels of both gas and particle-phase mercury in urban areas, possibly due to motor vehicles.

Mercury Speciation

- The speciation of mercury is important because it controls the fate of the mercury that is

emitted into the atmosphere, as demonstrated by a recent study of wet deposition of mercury to Lake Superior. In the study, modeled mercury deposition was two orders of magnitude higher when emissions from point sources were assumed to be mercuric chloride rather than elemental mercury. Regional Lagrangian Model of Air Pollution (RELMAP) simulation results also indicate that areas with the highest wet deposition of total mercury were associated with areas that have the highest emissions of Hg(II).

- Speciation also determines how much mercury enters the global pool. Researchers have used RELMAP data to estimate that approximately 98% of the elemental mercury emitted from combustion sources is transported outside the United States.

Atmospheric Chemistry

- Although Hg(II) can be emitted from sources, it can also be produced in the atmosphere via cloud water chemistry reactions. Although reactions between mercury and chlorine and mercury and ozone have been investigated, more work is needed in order to better understand the complex chemical reactions that occur in cloud water. More information is also needed about the relationship between mercury and particles, both inside and outside the cloud. Ultimately, atmospheric chemistry will determine the wet deposition of the mercury species and control its dry deposition.

- Urban studies indicate that vapor phase mercury tends to attach itself or absorb to particles from other sources. Since these particles can be quite large (e.g., >10 microns) this can result in high deposition of particulate mercury near urban sources.

- Elemental mercury and Hg(II) data from rural locations outside larger cities suggest that a natural process is occurring whereby the elemental mercury is converted to Hg(II). Variations in reactive gaseous mercury (RGM) concentrations also indicate that transport can have a significant impact on Hg(II) concentrations in the atmosphere.

- Additional research is needed to determine whether the marine boundary is a source of mercury to land surfaces and to better understand the chemistry and recirculation issues associated with the marine boundary layer.

- Based on recent studies in Barrow, Alaska, a huge loss of elemental mercury is caused by the chemistry related to the Arctic Sunrise phenomenon.

Importance of Dry Deposition

- Dry deposition occurs when mercury contacts the surface in the absence of precipitation.

- Dry deposition is currently believed to be the source of elevated mercury concentrations in

both thrufall and litterfall. (Note: Litterfall is the dominant source of mercury to the forest floor.)

- Vapor-phase mercury compounds tend to deposit very quickly, in part through interactions with large bodies of water. An examination of data from the Lake Michigan mass balance study indicates that dry deposition of reactive mercury is approximately two thirds of the wet deposition amount. Also, reactive and particulate mercury leads to elevated levels in mercury runoff.

Source-Receptor Relationships

- The sources of mercury deposited to various ecosystems are moving targets. Thus, efforts to determine the relative importance of natural vs. anthropogenic sources or long-range vs. local sources are often relatively unimportant.

- Deposition and source impacts were studied using a wide array of event/precipitation sampling sites in the Everglades from 1995 to 1996. Researchers determined that precipitation chemistry varies dramatically from sample to sample on an event basis. This variation was a function of meteorology.

- The Community Multi-Scale Air Quality model, which accounts for oxidant, acid rain, and particle chemistry, has been recently applied to the South Florida domain to assess how well it simulates atmospheric chemistry and deposition and to help users better understand what measurements need to be made. In general, the model showed that spatial patterns of mercury deposition are based on local meteorology and mercury emissions. Thus wet and dry deposition simulations varied substantially from day to day. The model also showed that elevated mercury deposition depends upon precipitation.

Mercury Atmospheric Deposition Science Questions Left to Be Answered

The following mercury science questions need to be answered:

- How important are atmospheric inputs in terms of the cycling of mercury to different ecosystems?

- Given the same aquatic ecosystems, do we know enough yet about the physical and chemical nature of the mercury deposition to be able to predict its fate?

- Is wet deposition equivalent to dry deposition? Is the form of mercury in wet deposition the same, and will it be processed in the ecosystem the same way the dry deposition is processed?

- Do we know enough about mercury deposition to simulate deposition to the experimental ecosystems?

- Atmospheric mercury science questions related to emission sources, emission characteristics, chemistry, wet deposition, and dry deposition need to be addressed.

- Is RGM deposition to the ocean as significant a global sink as what our present understanding leads us to believe?

3.2.2 Historic Perspectives on Mercury — *Don Porcella, Environmental Science & Management*

- An historic perspective on mercury can be used to identify factors that control its accumulation in biota via transformations, transfer, and cycling among compartments that are biological and physical.

- An historic perspective can also help identify and clarify 1) mercury's natural cycle and possible impacts from mankind's substantial use of mercury during the last 500 years, 2) the relative significance of changes in mercury emissions in terms of mercury loading to ecosystems, and 3) the relationship between mercury loading and monomethylmercury (MeHg) in fish.

- Although mercury comes from several significant natural and anthropogenic sources, anthropogenic sources have increased human exposure to mercury, raising concerns that the health of humans and ecosystems has been compromised.

- The development of a variety of tools has led to better understanding of mercury in the environment by providing scientists, engineers, and policy makers an historic perspective of how it cycles and accumulates in biota.

- Concerns about mercury exposures have led some countries to control mercury emissions and discharges, resulting in documented reductions in mercury exposures and bioaccumulation in certain locations.

- In the majority of cases, mercury loading to the environment in the United States is dominated by atmospheric deposition. Its subsequent transformation to and accumulation in fish as methylmercury constitutes almost the entire exposure to humans. Questions have been raised whether additional reductions of mercury emissions in the United States will result in reduced exposures to methylmercury, given background mercury circulation from global sources. Cost-effective strategies that result in measurable benefits in human and ecosystem health need to be developed.

- Mass balance data presented in1994 by Mason et al. indicate that current global mercury has increased by a factor of 5 over pre-industrial times, suggesting that reductions in anthropogenic emissions might be fairly effective in reducing loading.

- In 1995, Hudson et al. published a global model suggesting that a more careful inclusion of historic mercury uses could lead to a more accurate assessment of mercury exposure. Loss of mercury during precious metal extraction since the 1500s; industrial/commercial consumption of mercury since the 1850s; and an estimate of mercury's incidental release in combustion of fossil fuels, ore-roasting, and waste combustion were factored into the analysis.

- Comparison with lake cores provided some support for Hudson et al.'s analysis, which concluded that background (natural plus previous anthropogenic) could have accounted for about 60% of today's global circulation of mercury. Hudson et al. contended that increased oxidation of atmospheric mercury accounts for the observed increases in deposition.

- Based on the research to date, the following conclusions can made about mercury: 1) biotic mercury likely responds slowly to mercury deposition reductions, 2) global efforts will most affect marine fish, 3) global efforts will also reduce re-emissions and freshwater ecosystem mercury, and 4) there are signals from natural and anthropogenic events.

- It is clear, however, that additional research is needed. The following questions were identified as priorities for future research: 1) Why do ice cores and lake sediment cores show different resolution on inputs? 2) What role does the ocean play in the mercury cycle? and 3) What are the linkages between local, regional, and global cycles of mercury?

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